D. Any Technical Differences Between the WINForum and Apple Petitions Can, and Should, Be Resolved Within the Context of Industry Consensus-Building With Regard to the Spectrum Etiquette

The WINForum and Apple proposals, drafted largely without the benefit of each other's vision, are remarkably consistent. However, the two petitions are slightly different in some technical respects. As commenters have noted, the minor differences between the petitions, however, are not a basis for delaying the start of a rulemaking proceeding to allocate 5 GHz spectrum for unlicensed use.[61] Indeed, Apple and WINForum are already working together to iron out differences between the concepts, as expressed, and are confident that inconsistencies can be resolved within the context of industry-consensus technical forums to develop the spectrum etiquette for the band.

Nonetheless, WINForum recognizes that input on a few technical questions may be necessary to develop specifics needed for a Notice of Proposed Rulemaking. As an initial matter, there is a question as to the level of detail necessary in the etiquette and to what extent the etiquette must be codified in the Commission's rules. Although the actual etiquette will differ considerably, WINForum believes that the unlicensed PCS allocation regulations provide a sound framework for a 5 GHz allocation. In particular, WINForum believes that, while there is a role for voluntary adherence to higher level standards and interoperability criteria, a mandatory etiquette governing the conditions of access to the spectrum is necessary. This etiquette should be robust enough to limit destructive interference by devices, as well as

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[61] Apple Comments at 19; AT&T Comments at 9-10; Compaq Comments at 3-4; ITIC Comments at 6; Microsoft Comments at 5; Nortel Comments at 6.

ensuring that spectrum is used efficiently. The etiquette, however, should not be a device standard requiring interoperability, since that would have the effect of limiting innovation. To the extent that it may be desirable for classes of devices to interoperate, voluntary standards can and will be developed to address those needs. For the purposes of the Commission's rules, it is sufficient only to require that such devices are not inefficient or mutually incompatible.

Additionally, several parties have requested that the regulations for the band explicitly permit the use of directional antennas for transmitters. WINForum supports the unrestricted use of highly directional receive antennas. At this stage, however, WINForum believes it is premature to fully assess the effects of widespread use directional transmitters, and consequently believes that the permissibility of directional antennas should be taken up by the industry consensus technical committee. There are undoubtedly public interest benefits in sometimes extending the range of communications permissible in the 5 GHz band beyond the relatively short range envisioned as the principal requirement of SUPERNet. Also, directional antennas can increase spectral efficiency at short range in some regards, but there are a number of types of directional antennas, not all of which may be compatible with assuring the highest level of spectrum efficiency. Moreover, WINForum has not had the opportunity to discuss with the FAA and other potential band users the effects of directional antenna use on their operations.

Similarly, the need for strict channelization of the band and the role of centralized medium access are appropriate for resolution within an industry consensus committee.[62] Although a few parties have implied that WINForum has asserted the need for primacy of circuit-based communications, WINForum has only stated that, for reasons of efficiency, "[t]he use of a priority mechanism during contention resolution [between devices] *may* be beneficial in allowing traffic with differing importance to be serviced with differing rates of success."[63] WINForum believes that, as discussions between industry groups progress, the potential benefits and detriments of these mechanisms can be explored and that industry groups will be able to develop technical or other solutions to meet all users' needs.

As a final matter, WINForum notes that in developing its petition, it was striving to create a means for satisfying demands similar to those served by HIPERLAN in Europe. Community networking at distances of 10-15 kilometers, as proposed by Apple, was not addressed within the HIPERLAN standard, WINForum did not explicitly take up this issue in its petition. Before addressing the merits of this issue, however, WINForum believes additional information is needed on how such links would be implemented, the effects of such systems on the overall spectrum requirements for the band, the effect of such links on the efficiency of broadband data transmission schemes, the ability of longer distance systems to share spectrum with MSS and government radiolocation operations, whether existing

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62 Part 15 Coalition Comments at 8 n.18; TIA Comments at 3-4.

63 WINForum Petition at 20.

allocations can be used for such operations, and, whether the public interest requires that such links be co-located in the same band as shorter range broadband systems.

E. WINForum's SUPERNet Proposal Is Intended To Be Compatible With European HIPERLAN Developments

A few parties have misunderstood WINForum's position regarding compatibility between SUPERNet and HIPERLAN in Europe. WINForum believes that there are substantial public interest benefits in achieving compatibility between domestic and European device protocols for wireless broadband data transmission. Such compatibility would permit both domestic and European users the flexibility and ease of continuing to use their own computers and radio devices regardless of which side of the Atlantic they are on. Compatibility would also create a larger U.S./European market for wireless data products, thus lowering equipment prices in the United States and Europe. Moreover, harmonization of domestic and European protocols would provide a powerful incentive for other countries to follow with similar allocations using similar protocols, thus further expanding the base over which development costs can be recovered and further reducing the cost of devices for all users. As long as European standards do not constrain the ability of SUPERNet to meet the needs of domestic users, compatibility is in the public interest and should be encouraged.

There are many levels of compatibility that could be achieved between SUPERNet and HIPERLAN. At a minimum, WINForum believes that there should be spectrum compatibility; *i.e.*, devices should be able to operate on either side of the Atlantic with only changes to the software drivers controlling the radio interface. Beyond that, however, the question of the degree of compatibility between SUPERNet and HIPERLAN devices is a function of the industry consensus technical committee's ability to implement functionalities desired for domestic users in a manner consistent with the HIPERLAN specification.

III. CONCLUSION

As discussed above, the record in this proceeding demonstrates the need for immediate allocation of frequencies in the 5 GHz band to support the broadband data needs of wireless multimedia computer users. Such an allocation would have vast benefits for educational, medical, library, business, and industrial users. Indeed, in many cases SUPERNet-type devices can provide the only economically feasible means for such institutions to take advantage of the advanced multimedia resources of the National Information Infrastructure.

Since the types of offerings conceived for this band cannot be accommodated in other existing or proposed bands, the record strongly supports expeditious action by the FCC to initiate a formal rulemaking to further explore unlicensed broadband use of the 5 GHz band.

Respectfully submitted,

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A

Exhibit A. Ratio of Active to Inactive SUPERNet Nodes

WINForum, in appendix B to the petition, assumed the ratio of SUPERNet nodes with power on to the total number of deployed nodes (the active to passive node ratio of appendix B) was 0.01. This is the same ratio assumed by ETSI for HIPerLAN. The following shows that this ratio is conservatively low.

First, consider the information throughput at a particular device at 1 percent transmitter on time:

Raw data rate	24.5 Mb/s
50 % efficiency	12.2 Mb/s per channel
1 % of 12.2 Mb/s	122 Kb/s/node

Thus, if a node transmitter is on 1 percent of the time, the node achieves approximately 120 Kb/s of throughput capacity. The question then reduces to whether the mean throughput demand will ever exceed 120 Kb/s/user when averaged over a large area, namely that area over which the devices might interfere with a satellite.

The SUPERNet throughput density objective in dense deployment is approximately 200 Mb/s/hectare which is comparable to the HIPERLAN objective of 120 Mb/s/hectare. This is the maximum mean throughput demand that will be accommodated averaged over a single location. At 1000 users per 10,000 square meters, this is 200 Kb/s/user. The multi-metropolitan composite average will be considerably less than 122 Kb/s/user if the maximum average throughput demand at the busiest locations is 200 Kb/s/user. Thus, the mean transmitter on time during busy periods will be less than 1 percent. Note that this does not consider the fact that not all devices will be in use at any particular time.

Another approach can be taken to show that 1 percent on time is conservative. The following throughput demand estimates were made by WINForum as the basis for predicted spectrum requirements for packet LANs in the US.

Office automation now	1 Kb/s/user
Future typical office	10 Kb/s/user
Maximum office automation	60 Kb/s/user
Typical collaborative user-future	120 Kb/s/user
Maximum collaborative user	400 Kb/s/user

As an example, 20 percent collaborative use plus 80 percent office use is a high estimate of the predictable usage division ofer a large area. The result is 32 Kb/s/user mean throughput at the typical rate, and 128 Kb/s/user at the maximum rate for a location. It is not likely that the average use will exceed the 32 Kb/s typical rate over the wide area seen by a satellite. Thus, the 1 percent assumption which achieves 122 kb/s/user leaves considerable capacity margin for future multi-media use as well as packet data.

These estimates must be further reduced to account for the fact that not all nodes will have power on and be in use at any time. That is, only some small fraction will actually be in use for communication purposes. For this reason as well as the magnitude of the overall throughput demand, an average 1 percent transmitter on time over a wide area is a very pessimistic assumption.

CO-EXISTENCE OF RADIO LOCAL AREA NETWORKS WITH THE MICROWAVE LANDING SYSTEM

T A WILKINSON AND S K BARTON

(04/08/92)

1 INTRODUCTION

The aim of this study was to investigate the co-existence of radio LANs (local area network) with the MLS (microwave landing system) in the band 5.00GHz-5.25GHz. This paper presents a general methodology which is used throughout in the calculation of interference levels for various scenarios. Interference from the radio LAN to the MLS only is considered. Based on the calculations radio LAN exclusion zones around MLS equipment are defined. Interference reduction using spread spectrum techniques is discussed. Finally, conclusions and suggestions for further work are presented.

2 GENERAL METHODOLOGY

2.1 Radio LAN Parameters

A set of radio LAN parameters were proposed in a co-existence study for the 5.25GHz-5.85GHz band carried out by the UK RA [1]. These parameters were based on the DECT (digital european cordless telecommunications) system which has many similarities to a radio LAN system in radio aspects and operating environment. The radio LAN parameters used in this study are based on these and are given in table 1. These parameters are for a narrow-band system no spectrum spreading is assumed at this point.

PARAMETER	VALUE
Maximum EIRP	30dBm
Bit Rate	15Mbits^{-1}
Bandwidth	20MHz
Required C/I	20dB
Maximum Tolerable Interference	-131dBW/20MHz
Receiver Threshold	-81dBm
Antenna Gain	2dBi

Table 1 Radio LAN Parameters

The radio LAN maximum EIRP (equivalent isotropic radiated power) is scaled from that for DECT, which is 24dBm in a 1.7MHz bandwidth, according to the higher transmission loss at the higher frequency, the increased bandwidth and the reduced coverage. This gives a maximum EIRP of 30dBm.

The radio LAN bandwidth is scaled from that for DECT, which is 1.7MHz for a bit rate of 1.2Mbits^{-1}, according to the increase in bit rate to 15Mbits^{-1}. This gives a bandwidth of 20MHz.

The radio LAN maximum tolerable interference is simply the thermal noise power in the equivalent noise bandwidth of the radio LAN.

The required C/I is an approximate figure and comparable with that for DECT.

The receiver threshold is calculated from the required C/I and the maximum tolerable interference.

The radio LAN antenna gain is 2dBi, which is reasonable for a simple antenna, omni-directional in a horizontal plane (half wave dipole). However, radio LANs may use directional antennas to reduce time dispersion of signals by attenuating reflected components. In this case a maximum antenna gain can be calculated based on the maximum aperture available on a portable computer. The wavelength λ, at 5GHz is approximately 6cm and hence the maximum aperture diameter is around 12cm or 2λ. The maximum directive gain for an aperture diameter expressed in wavelengths D_λ, is

$$G = 10\log(\pi^2 D_\lambda^2) \qquad \textbf{(1)}$$

This gives a maximum directive gain of 16dB and assuming 40% efficiency a maximum overall gain of 14dB.

The following further parameters given in table 2 have been assumed for the out-of-band emissions of a radio LAN system. These figures were derived from the DECT specifications [2], based on specified out-of-band emissions and in-band power level, 24dBm in a 1.7MHz bandwidth.

FREQUENCY OFFSET FROM BAND EDGE	POWER LEVEL RELATIVE TO IN-BAND POWER
0MHz-5MHz	-38dB
5MHz-10MHz	-42dB
10MHz-20MHz	-48dB
20MHz-30MHz	-52dB
>30MHz	-58dB

Table 2 Out-of-Band Emissions of Radio LAN

2.2 Interference Calculation

All the following interference calculations are based on establishing an MCL (minimum coupling loss) which is defined as the minimum power loss between the system and its interferer for maximum tolerable interference level.

$$MCL = P_i + 10\log\left(\frac{BW_s}{BW_i}\right) - I_s \qquad \textbf{(2)}$$

P_i is the interferer signal power, BW_s and BW_i are the respective bandwidths of the system (noise bandwidth) and the interfering signal and I_s is the maximum tolerable interference level. The second term in the expression accounts for the interferer power falling in the system bandwidth. If the bandwidth ratio is greater than unity and all the interferer power falls in the system bandwidth this term is zero.

It is assumed that the interferer can be treated as band-limited white noise. However, a thorough investigation of interference effects requires integration of the total interference but this requires accurate knowledge of the interferer signal spectrum and system frequency selectivity (rejection) both of which are difficult to obtain for the existing systems and are un-available for radio LANs. Hence, the MCL must suffice.

If a number of interferes in a particular location are considered then the interferer signal powers must be added and the MCL increased according to the increased interferer power. For example, if there are 10 interferers then the MCL would be increased by 10dB.

The MCL is achieved by adequate geographical separation of the two systems considered. The TL (transmission loss) must be greater than the MCL to ensure sufficient attenuation of signals from the interferer to the system. The TL in dB is,

$$TL = 20logf + 10nlogd - K - G_t - G_r + A \tag{3}$$

where f is frequency in Hz, n is the decay index (2 for free space, 4 for close-to-ground propagation), d is distance in m, G_t and G_r are the transmit and receive antenna gains and A is any additional loss such as building penetration losses, K is a grouping of fundamental constants given by:

$$K = 20\log\left(\frac{c}{4\pi}\right) \tag{4}$$

The derivation of this equation is given in [3]. The TL is used in the following calculations to calculate a minimum separation distance of the system and its interferer and this distance can be used to specify the radius of an interferer exclusion zone around the system.

The typical values for n and A used in the following calculations are based on measured values for buildings [4]. These were used in the absence of any measured values for aircraft. It is thought that propagation in aircraft will not be too dissimilar to propagation in buildings.

3 CO-EXISTENCE WITH MICROWAVE LANDING SYSTEM

3.1 Introduction to Problem

The MLS system currently uses the band 5.00GHz-5.15GHz although the entire band 5.00GHz-5.25GHz has been reserved for this system.

Radio LAN systems may be given spectral allocation in the band 5.15GHz-5.25GHz if it can be shown that the operation of radio LAN systems in this band will not adversely effect the MLS system.

The MLS system may in the future expand into its entire allocated bandwidth. Hence, two scenarios must be investigated.

1) MLS and radio LANs co-existing in the same band

2) MLS and radio LANs co-existing in adjacent bands

3.2 The MLS System

The MLS system is an aircraft navigational/guidance system for angle and distance measurement. Signals are transmitted from antennas on the ground and received by antennas on the aircraft. All received signals are interpreted in the MLS equipment on the aircraft. MLS system parameters are given in table 3. These parameters were extracted from [5] and [6].

PARAMETER	VALUE
Bandwidth	150kHz
Thermal Noise Power	-123dBm (150kHz)
Maximum Tolerable Interference	-120dBm (150kHz)
Co-Channel Tolerable	C/I > 25.0dB
Adj-Channel Tolerable	C/I > -20.5dB(1st) C/I > -25.0dB(2nd)
Minimum Signal Strength	-95dBm
Antenna Gain	0dBi
System Frequency Selectivity (Rejection)	> 40dB (5.092GHz-5.250GHz) > 75dB (>5.250GHz)

Table 3 MLS Parameters

3.3 Interference Scenarios

MLS systems operate at higher power levels for greater coverage than radio LAN systems and hence interference problems should only occur in a near-far scenario when a radio LAN transmitter is close to an MLS receiver. There are two possible near-far scenarios

1) Where a radio LAN on an aircraft is close to the aircraft MLS receiver.

2) Where many radio LANs are in a multistorey building close to the aircraft approach path to the airport and hence close to the aircraft MLS receiver.

Scenario (1) is the more likely scenario because radio LANs or portable computers with radio LAN cards may be used by passengers on aircraft. However, the use of radio LAN systems on aircraft could be prohibited avoiding this scenario completely. In this scenario the maximum signal from the radio LAN transmitter to the MLS receiver could be **either** through propagation out of the aircraft and to the MLS via its antenna **or** through propagation along the body of the aircraft and to the MLS via its casing. The former should be easier to estimate as it simply involves a penetration loss and path loss. The latter requires detailed information about the EMC (electromagnetic compatibility) specifications of the MLS equipment and casing. In either case the transmission loss is likely to be similar involving a similar distance and a similar additional loss.

Scenario (2) is the less likely scenario because multistorey buildings are not built close to aircraft approach paths to airports for safety reasons. Such buildings are typically 1km from the approach path. Also, at such distances the MLS signal strength at the aircraft will be much greater than the minimum signal strength given in table 3 which is calculated for the limit of the MLS coverage volume. At this limit of the MLS coverage volume the aircraft will be at a high altitude and any signals from radio LANs in buildings should be sufficiently attenuated by the large path loss.

To investigate whether there is a potential interference problem in either of the above scenarios we must determine a radio LAN transmitter exclusion zone radius around an MLS receiver. The MCL and consequently the minimum separation distance are evaluated for MLS and radio LANs co-existing in the same and adjacent bands in the following sections.

3.4 MLS and Radio LANs in the Same Band

The MCL for this scenario is

$$MCL = 30 - 21.2 + 120 \qquad \textbf{(5)}$$

128.8dB (above values are in dBm). This is based on the figures given in table 3.

The transmission loss must be greater than the calculated MCL. At 5.20GHz the transmission loss is

$$TL = 46.8 + 10n\log d - G_t - G_r + A \qquad \textbf{(6)}$$

which reduces to

$$TL = 44.8 + 10n\log d + A \qquad \textbf{(7)}$$

using the parameters given previously.

If free space propagation is assumed, the decay index n is 2, and additional loss A is 3dB. The minimum separation distance d is 11.2km.

Hence, in this case there is a serious potential problem and the use of radio LANs on aircraft would have to be prohibited and radio LAN exclusion zones would have to be imposed around airports.

3.5 MLS and Radio LANs in Adjacent Bands

As stated previously, a thorough investigation of interference effects requires integration of the total interference. As this is not possible, the following calculations are based on the in-band adjacent band interference only. It can be shown, by comparing the magnitudes of in-band and out-of-band interference, that this is valid. The out-of-band emissions of the radio LAN are -58dB relative to the in-band power of the radio LAN, from table 2, but the rejection of the MLS system of out-of-band signals is -40dB system frequency selectivity plus -25dB adjacent channel tolerance giving a total of -65dB. Hence, the out-of-band adjacent band interference is negligible compared to the in-band adjacent band interference.

For the in-band adjacent band interference the figure for the interferer power P_i must be determined from the out-of-band emissions of the radio LAN system. If these are taken to be -58dB (table 2) relative to the in-band power which is 30dBm, P_i is -28dBm. Hence, the MCL for this scenario is

$$MCL = -28 - 21.2 + 120 \tag{8}$$

70.8dB (above values are in dBm).

The transmission loss must again be greater than the calculated MCL. Using equation 7 and the previous assumptions, n of 2 and A of 3, the minimum separation distance d is 14.1m. This is a pessimistic estimate for the exclusion zone radius as it is based on small values for the decay index n and additional loss A. If n is increased to 3 and A to 10dB, which are more realistic figures considering that there will be no direct line of sight between the radio LAN and the MLS equipment, the minimum separation distance is 3.4m. This distance suggests that there would be no significant interference problem between radio LANs on an aircraft and the MLS equipment. However, we must consider the possibility that the radio LAN antenna has a gain of 14dB and the direction of maximum radiation direction is towards the MLS equipment. The minimum separation distance in this case is 56.2m, with n and A equal to their original values of 2 and 3dB. In this case there could be an interference problem as the exclusion zone radius is large. However, this is an unlikely worst case scenario and if, again, n is increased to 3 and A to 10dB for the same antenna gain the minimum separation distance is 8.6m. Hence, even with this large antenna gain and the direction of maximum radiation towards the MLS equipment there will be no interference problem so long as there is no line-of-sight between the radio LAN antenna and the MLS equipment antenna. In any case if steerable beam antennas are employed power control will also be employed. When a link has not been set-up the antenna will have an omni-directional pattern and power will be uncontrolled but when the a link has been set-up the antenna will have a directional pattern and the power will be controlled and hence the likelihood of simultaneously having maximum gain and maximum EIRP is negligible.

In the above arguments we have only considered one interfering radio LAN simply because it is unlikely that there will be more than this being operated in close proximity to the MLS equipment on an aircraft in scenario (1) and hence, we do not need to consider the additive interference effects.

There may be a large number of potential interferers in scenario (2) but as we have shown from the minimum separation distances calculated, there should be no potential interference problem in scenario (2). This is illustrated in the following calculation. If we assume for example that there are 10 buildings within 1km of the aircraft approach path and 10 radio LANs in each of these buildings giving a total of 100 radio LANs at 1km. The MCL for this example must be increased by 20dB to 90.8dB. The transmission loss must be greater than the calculated MCL. Using equation 7 and the previous assumptions, n of 2 and A of 3, the minimum separation distance d is 141.2m. Hence the MLS system could tolerate 100 radio LANs at 141.2m and this is based on pessimistic propagation constants equivalent to every radio LAN having a clear line-of-sight obstructed only by a soft partition such as a window. Hence, there is no potential interference problem in scenario (2).

3.6 Interference Reduction With Spread Spectrum Techniques

Applying spread spectrum techniques to a narrowband signal expands the bandwidth of the signal by the bandwidth expansion factor of B_e and reduces the power spectral density of the signal by the processing gain G_p which is equal to the bandwidth expansion factor $_eB$ in dB. If spread spectrum techniques are applied to the 20MHz bandwidth narrowband radio LAN signal and the maximum available bandwidth is 100MHz consequently the maximum available B_e is 5, and G_p is 7dB. The power spectral density of the entire signal is reduced by 7dB.

Hence, the application of spread spectrum would reduce the minimum separation distance from 11.2km to 5.0km for MLS and radio LANs in the same band and from 14.1m to 6.3m for MLS and radio LANs in adjacent bands. (all figures are for a bandwidth of 20MHz, n of 2 and A of 3dB).

So far we have not made a distinction between DS (direct sequence) and FH (frequency hopping) spread spectrum as the same reduction in power spectral density is achieved with both techniques.

However, there may be a difference in the spectral roll off and hence the level of adjacent band interference of DS and FH. This requires further investigation.

4 CONCLUSIONS

This study has shown that MLS and radio LANS will not be able to co-exist in the same band but will be able to co-exist in adjacent bands provided that there is a radio LAN exclusion zone of approximately 10m around the MLS equipment on an aircraft. A restriction could be imposed prohibiting the use of radio LANs in aircraft to ensure that there would be no significant interference problem. However, it should be noted that the above minimum separation distances were calculated with pessimistic propagation parameters and in practice the transmission losses could be much larger reducing the interference levels. Measurements are required to determine actual transmission losses in aircraft. The use of spectral spreading reduces interference and hence is advantageous. Also, there may be a difference in the spectral roll-off and hence the level of adjacent band interference of DS and FH spread spectrum. This requires further investigation. It should be stressed that if there is any significant change in radio LAN parameters from those used in this study the above minimum separation distances should be re-calculated.

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